Electromagnetic Excitation Rates for Nuclear Isomers in a Hot Dense Plasma

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Nuclear isomers play an important role in the nucleosynthesis of isotopes in weapons and stellar explosions. At the high temperatures and densities available in the hot dense plasmas of interest to both weapons physics and astrophysics there is the possibility of populating nuclear isomers electromagnetically. In this project we examined the rates for electromagnetic excitation of the isotopes of several isomers of interest both in astrophysics and applied physics. We consider six possible electromagnetic processes, namely, photo-absorption, inverse internal conversion, inelastic electron scattering, Coulomb excitation, (γ,γ), and $(e,e'\gamma)$ reactions.

The electromagnetic excitation rates for all of these processes depend on the temperature of the plasma, the excitation energy of the isomer, and the lifetime of the isomer. To simplify calculations, we assumed that nuclei are completely stripped of their electrons in the plasma. We derived expressions for these electromagnetic processes and examined the rates for several nuclear isomers. Of particular interest for applied physics are the low-lying isomers of ^{235}U, ^{193}Ir, ^{87}Y, ^{88}Y. The half-lives of these isomers range from 0.3 msec to years and their excitation energies from ~77 eV – 2.5 MeV.

The Feynman diagrams representing the electromagnetic processes considered are shown in Fig. 1. We find that for plasma temperatures of kT ~ 1 – 10 keV the reaction rates for electromagnetic populations are negligible. Thus, these isomers can only be populated by neutron excitation in the explosive environments of interest. Thus, we conclude that weapons radiochemical calculations of the nucleosynthesis of unstable nuclei need not include electromagnetic excitation of isomers.

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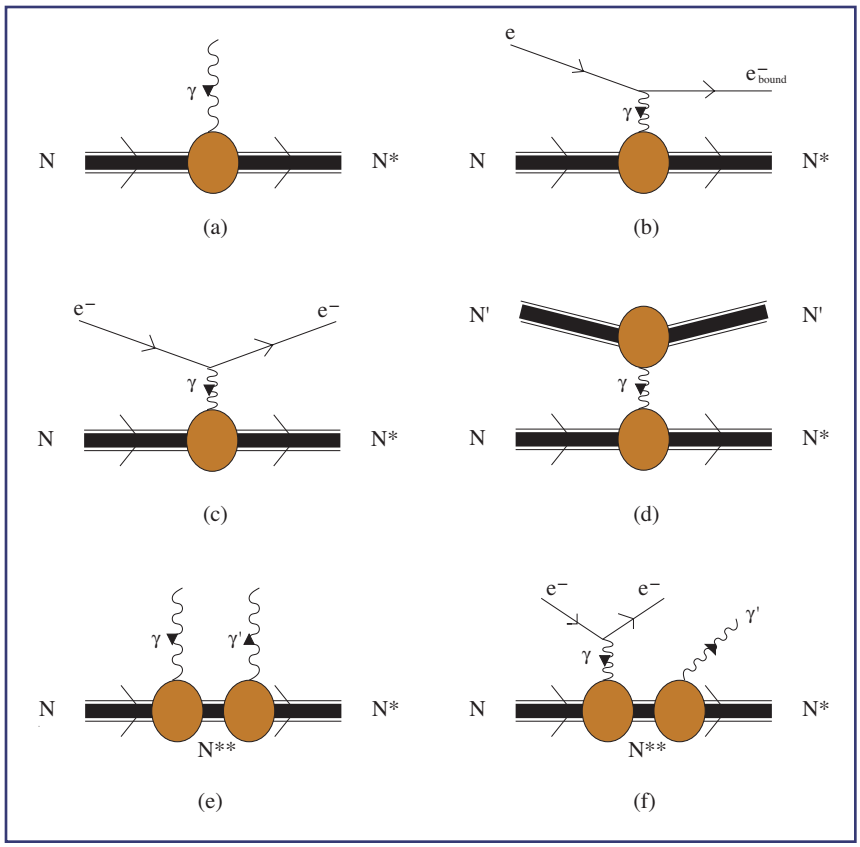

Figure 1— Feynman diagrams representing the electromagnetic processes considered in this paper. Plot (a) represents photoexcitation. Plot (b) represents inverse internal conversion, where the final electron is bound. Plot (c) shows electron scattering, where the final electron belongs to the continuum. Plot (d) shows ion-excitation, where N' is another ion. Plot (e) shows γ,γ′ excitation. Finally, Plot (f) shows e,e′γ excitation.